WPS4047

# Unraveling the Worldwide Pollution Haven Effect*

Jean-Marie Grether †, Nicole A. Mathys ‡, Jaime de Melo §

Abstract

This paper contributes to the debate on the existence of pollution haven effects by systematically measuring the pollution content of trade (measured by the pollution content of imports (PCI)) and decomposing it into three components: a 'deep' component (i.e. unrelated to the environmental debate but including variables traditionally present in the gravity model) and two components (factor endowments and environmental policies) that occupy centerstage in the debate on trade and the environment. The decomposition is carried out for 1986-88 for an extensive data set covering 10 pollutants, 48 countries and 79 ISIC 4-digit sectors. Illustrative decompositions presented for 3 of the 10 pollutants in the data set indicate a significant pollution haven effect which increases the PCI of the North because of stricter environmental regulations in the North. At the same time, the factor endowment effect decreases the PCI of the North as the North is relatively well-endowed in capital and pollution-intensive activities are also capital intensive. On a global scale, because the bulk of trade is intra-regional with a high North-North share, these effects are small relative to the 'deep' determinants of the worldwide pollution content of trade. In sum, although the impact has been stronger on vertical (North-South) trade flows, differences in factor endowments and environmental policies have only marginally affected the pollution content of world trade during the 1986-88 period.

JEL Classification numbers: F18.
Key Words: Trade and the environment, pollution haven

World Bank Policy Research Working Paper 4047, November 2006



*We thank Marius Brülhart, Olivier Cadot, Matthew Cole, Céline Carrère, Robert Elliott, Jaya Krishnakumar, Carlos Ordas, David Wheeler, and participants at the ETSG meeting in Dublin (2005) for comments on an earlier draft. Financial support from the Swiss National Fund under research grant No 100012-109926 is gratefully acknowledged.

†University of Neuchâtel, Pierre-à-Mazel 7, 2000 Neuchâtel, email: jeanmarie.grether@unine.ch
‡University of Lausanne, e-mail: nicole.mathys@unil.ch
§University of Geneva, CERDI, CEPR, and WBER editor: email: demelo@ecopo.unige.ch

# 1 Introduction

For the environmentally minded, globalization reflected in rising trade shares in world GDP is worrisome, directly because the activity of trading itself generates pollution, and indirectly because lower environmental standards generate a comparative advantage in "dirty" industries for developing countries. In this context, globalization, which reduces transport costs and/or trade barriers, would shift investment and production of "dirty"goods to the South. As a result, globalization would lead to an increase in the pollution content of imports by the North, in conformity with what has been called the "pollution haven (PH) *hypothesis*", and to a worldwide increase in the production of dirty products. Likewise, the literature has emphasized that a tightening of environmental standards in the North would lead industries to relocate to the South according to what is referred to as the "pollution haven (PH) *effect*". Overall, it is fair to say that empirical support for the PH hypothesis is weak, while the PH effect, which is often taken for granted, has proven elusive too, apart from recent empirical support for the US.

One often-mentioned culprit is lack of data: only the US has time series on abatement costs at the industry level, and the only comprehensive data set on emissions is also for that country and for one year (the 1987 IPPS data elaborated by the World Bank). Although the PH effect is obviously a worldwide issue involving rich and poor countries, faced with this lack of data, researchers have made progress on the PH debate by carrying out what we would call "partial" studies. First, the effects contributing to the location of economic activity (see the illustrative example in section 2) have been analyzed in the context of firm case studies (e.g. Eskeland and Harrison (2002)). Second, progress has also been made by case studies of a particular pollutant (e.g. Antweiler et al. (2001) for $SO_2$ emissions). Third, many studies have been carried out on the US where recent evidence controlling for unobserved heterogeneity and the endogeneity of environmental policy has detected a significant PH effect (Ederington et al (2004, 2005) and Levinson and Taylor (2005) using a panel data set of US industries). And fourth, when covering more countries, the analysis is often limited to specific sectors (e.g. Cole and Elliott (2003)). In the absence of systematic data on emissions across countries, making progress has been largely limited to gathering fragmentary evidence (see e.g. Copeland and Taylor (2003) for a review).

In this paper we go beyond partial evidence and carry out a more systematic global estimation of the pollution content of trade across all industrial sectors in which we disentangle the role of factor endowments and environmental policies from the more fundamental (or "deep") determinants of bilateral trade. To our knowledge, such a decomposition exercise, which allows one to get a better handle on the PH effect, has not been carried out previously. As an example of what transpires from a global decomposition exercise, consider the usual version of the PH effect, according to which a tightening of Northern environmental standards will increase the pollution content of imports by the North. But what about the South? In reality, developing countries are also importing dirty products, and they may even be larger importers of those goods if one takes into account the fact that highly polluting activities are often capital-intensive. In addition, the pollution content of global trade depends on composition effects since trade involves not only North-South trade, but also North-North and South-South trade. The decompostion framework proposed in this paper weighs the importance of the PH effect relative to other contributing factors.

Section 2 discusses briefly the pollution haven hypothesis and the pollution haven effect, arguing that it can be usefully captured by the pollution content of trade (in our case, the pollution content of imports), and specifying how it can be measured. Section 3 estimates a model of bilateral trade in emissions (one for each pollutant) in which factor endowments, environmental policies, and 'deep' determinants (i.e. all remaining determinants) are separately identified. These estimates then serve to identify the relative importance of the pollution haven effect with respect to the factor endowment effect in the worldwide pollution content of trade. Because of data limitations on emissions over time, computations are carried out in cross-section so that the paper's estimates must be considered with caution, it being hoped that the approach developed here will yield more conclusive results when better emission data becomes available. Section 4 concludes.

# 2 The Pollution Content of Trade: A Framework

We show first how the pollution content of trade can be used to study the pollution haven and the factor endowment effects. We then introduce the total and average measures to be analyzed subsequently.

## 2.1 The Pollution Haven Effect

To fix the terms of the debate about the PH effect, and to motivate the choice of the pollution content of imports (PCI)[1], consider the following simple hypothetical example in a Heckscher-Ohlin framework. Two countries, North (N) and South (S), produce two goods, a dirty and a clean good, with pollution per unit of output of the dirty good being identical in N and S. Both countries are the same in all respects except that N has a higher income per capita than S. Assume that environmental quality is a normal good. Then N will have stricter environmental standards and will import the dirty good and hence its trade will be "embodied" with emissions. Conversely, S will import the clean good from its partner and so the PCI of S will be zero. Therefore, in this two-commodity world, the PCI of N from S is positive ($PCI_{NS} > 0$), and the PCI of S from N is zero ($PCI_{SN} = 0$; in a multi-commodity world, $PCI_{NS}$, $PCI_{SN} \neq 0$,

[1] We could have carried out the analysis by measuring the pollution content of exports. Since the econometric analysis is carried out on bilateral trade, both approaches are in effect equivalent. Because export data are less reliable, we use imports to minimize mismeasurement.

$PCI_{NS} > PCI_{SN}$). Note that world pollution has increased with respect to the autarkic equilibrium.

Next, consider two experiments. First, consider globalization via a reduction in transport costs, or a reduction in trade barriers. This will lead S to specialize in the production of dirty products. Globalization thus increases $PCI_{NS}$ in conformity with what has been called the *PH hypothesis* (the previously dirty production in N is now carried out in S under less-stringent environmental standards). As a second experiment, consider a tightening of environmental regulations in N. This is also expected to lead to a relocation of dirty industries from N to S, increasing $PCI_{NS}$ through what is referred to as the *PH effect* in the literature.

Bring in now factor endowment differences, supposing that dirty industries are capital intensive and that N is relatively well-endowed in capital. If the PH effect were small (as suggested by recent US-based evidence mentioned above), then the factor endowment influence (*FE effect* for short) on comparative advantage could well dominate. Let us assume this is the case. Then, S will be importing the dirty good although it has lower environmental standards, a configuration refered to as reflecting the *FE hypothesis* according to Copeland and Taylor (2004). Starting from this new configuration, consider again the two above experiments. With globalization resulting in a reduction in transport costs and/or trade liberalization, dirty activities might move to N, resulting in larger dirty imports of S from N. Conversely, a tightening of environmental policy in N will have the reverse effect, with dirty activities moving to S and hence implying a decrease in $PCI_{NS}$. Ultimately this may lead to a reversal in comparative advantage.

Thus, the relative strength of the PH versus the FE effect is determinant in shaping the worldwide allocation of the PCI between country groups. It also plays a crucial role regarding the impact of globalization or environmental policy changes on the pollution content of trade.

To get a full picture of the factors underlying the evolution of the worldwide pollution content of trade, scale (N and S have different economic weight and both may grow) and technical (abatement activities are different in N and S and vary across time) effects should also be factored in, as well as differences in emission intensities across pollutants. And since the debate on trade and the environment is usually couched in terms of the contribution of rich and poor countries, compositional effects across regions should also be taken into account. Because of limitations on the availability of data on emissions, this paper only explores the determinants of the PCI at one point in time, thereby abstracting from temporal effects.

## 2.2 Measuring the PCI

In practice, since pollution intensities vary across sectors and pollutants, an appropriate measure of the PCI must distinguish between the different pollutants and take into account sector heterogeneity at a reasonably disaggregated level.[2] Denote $M_{ijs}$ the value of bilateral imports of country $i$ from country $j$, in sector $s$, and let emissions per dollar of production in country $j$, sector $s$ and pollutant $k$ be given by $g^k_{js}$. Then, the *total* ($Z^k_{ij}$) and *average* ($G^k_{ij}$) PCI of country $i$ from country $j$ for pollutant $k$, are given by:

$$Z^k_{ij} = \sum_s g^k_{js} M_{ijs} \; ; G^k_{ij} \equiv \frac{Z^k_{ij}}{M_{ij}} = \sum_s g^k_{js} \mu_{ijs} \tag{1}$$

where $M_{ij} \equiv \sum_s M_{ijs}$ and $\mu_{ijs}$ is the share of sector $s$ in country $i$ imports from country $j$.[3] This indicator covers the whole distribution of industrial sectors and its value is sensitive to differences in emissions across industries and pollutants.

The only comprehensive data on emissions are the 1987 US emissions coefficients computed for 79 4-digit ISIC industries. Note that, abstracting from the damage caused by the activity of transporting goods, if all countries had the same emission coefficients, the location of economic activity would not matter. However, it is clear that US coefficients cannot be applied to a large sample of countries that includes developed and developing countries. In order to estimate country-specific emissions, we draw on the results in Hettige et al (2000), who find that emissions per employee are roughly constant across countries.[4] Thus we can adjust the US per employee IPPS coefficients, $h^k_{US,s}$, by each country's industry labor-output ratio $\left(\frac{L_{js}}{X_{js}}\right)$ ,i.e. $g^k_{js} = h^k_{US,s}\left(\frac{L_{js}}{X_{js}}\right)$. This amounts to assuming that emissions per dollar are inversely proportional to labor productivity. While this adjustment to US coefficients seems reasonable, we abstain from extending it to other years since changes in emission intensities over time are not determined only by labor-productivity changes.[5]

Changes in the volume of pollution embodied in worldwide trade (i.e. in PCI) is the simplest, most direct, and perhaps most reliable global indicator of the PH effect. Here we use average and total PCIs over 79 4-digit ISIC industries

[2] The traditional approach relies on the less accurate comparison between "clean" and "dirty" sectors. It is true that, at the 3-digit ISIC level, the group of "dirty" sectors (reported in table A2 in Appendix 2) does not seem to change much across pollution criteria (e.g. actual emissions vs. abatement costs, see Mani and Wheeler (1997)). However, the definition of "clean" sectors is more ambiguous, and the intermediate sectors that are dropped from the usual analysis of clean vs. dirty industries often represent a substantial part of the PCI (up to 50% for some pollutants according to our estimates, see table A3 in Appendix 2). Moreover, at the 4-digit ISIC level, the classification of dirty sectors is not robust across pollutants. Two examples taken from the IPPS coefficients of the World Bank, establish the superiority of our approach. Take first the manufacture of leather products (ISIC 3233) which is one of the cleanest activities in terms of $SO_2$ released in the air, but also one of the most polluting ones in terms of metal toxic pollution. Take next sugar factories and refineries (ISIC 3118): it has the opposite pattern, releasing much $SO_2$ in the air, but negligible toxic pollution. Overall, more than a quarter of ISIC 4-digit categories exhibit a similar pattern, ranking in the top ten most polluting sectors according to one pollution criteria and among the ten cleanest according to another.

[3] Muradian et al. (2002) and Ederington et al (2004) use a similar indicator.

[4] We thank David Wheeler for this suggestion.

[5] In an exploratory setting, using additional time-series data on $SO_2$ emissions in China, Grether et al. (2006) construct a time-series of emissions for a similar sample of countries.

for 29 developing and 19 developed countries and 10 pollutants.[6] Due to space constraints, we only report results for a selection of three pollutants[7]: $SO_2$ in the air ($SO_2$), widely used in other studies, total toxic pollution (TPTT) and biological oxygen demand in water (BOWT)[8]. All three pollutants generate relatively small transborder externalities beyond those embodied in trade.

# 3 Unraveling the Pollution Haven Effect

From equation (1) above, it is clear that the PCI in bilateral trade will be given by emissions per unit of trade times the volume of trade, the latter depending in turn on environmental policy, factor endowments and other "deep" determinants, i.e. determinants unrelated to endowments or environmental policies. Omitting pollutant superscript $k$ for simplicity, the PCI of country $i's$ imports from country $j$, $Z_{ij}$, can be decomposed multiplicatively into a "deep" determinant component, $\Omega_{ij}$ (i.e. the import- embodied pollution that would occur for reasons unrelated to environmental policy and endowments), a FE effect, $\kappa_{ij}$, and a PH effect, $\ell_{ij}$:

$$Z_{ij} = \Omega_{ij}\kappa_{ij}\ell_{ij} \tag{2}$$

This multiplicative form appears reasonable and easy to handle, particularly in a gravity-like framework. When we want to abstract from the PH effect, the FE effect or from both simultaneously, this amounts to assume that $\ell_{ij} = 1$ or $\kappa_{ij} = 1$ or $\ell_{ij} = \kappa_{ij} = 1$ respectively.

We proceed in two steps. In a first step, we regress for each pollutant $k$, the bilateral PCI, $Z_{ij}^k$, on a set of explanatory variables capturing the effects identified in equation (2). Having checked that the estimated coefficients are plausible and the overall fit satisfactory, in a second step, we use the estimated coefficients to decompose the total predicted PCI for each pollutant into the three components, namely "deep", "FE", and "PH" effects.

[6] The split between developed and developing countries was carried out using 11,000$ per capita as the break point, which corresponds to a trough in the bimodal distribution of incomes per capita. Other cut-off values are considered in section 3.2.

[7] Results for the other pollutants are available from the authors upon request. They will be mentioned in the text when they differ markedly from those for the three selected ones.

[8] $SO_2$ is mainly emitted by fossil fuel combustion. It may cause respiratory diseases and damage trees and crops. It is also a prime source of acid rain, which damages forests and buildings and contributes to the acidification of lakes and streams. Toxic pollution is measured as toxic chemicals in air, land and water (the rank correlation between the total measure and the media-specific measure is 0.93 for air, 0.87 for land and 0.46 for water). It causes damage to internal organs, neurological functions and can result in decreased hutching success, reproductive problems and cancers. Biological oxygen demand in water measures how much oxygen is being used by aerobic microorganisms to decompose organic matter (e.g. dead plants, leaves, manure, sewage, food waste). If these bacteria are using too much of disolved oxygen, then there will not be left enough for other organisms.

### 3.1 Determinants of the PCI

We want now to isolate the effects of environmental policies and factor endowments on the PCI. The PH effect is captured by differences in the lead content of gasoline which is our proxy for environmental policy.[9] The capital-labor ratio serves as proxy for endowment differences, i.e. for the FE effect. Table 1 summarizes the sample characteristics of these variables for each group of countries along with the average PCI values for each group of countries. The figures confirm intuition. The average lead content is higher in the South and hence low income countries have lower environmental stringency. Likewise, the capital-labor ratio is on average higher in the North. Finally, $PCI_N > PCI_S$ for each one of the three pollutants.

**Table 1 here**: Summary Statistics by Income Group

The empirical specification is given by equation (3) below. It is inspired by the gravity framework, previously used in cross-country studies of trade in pollution-intensive activities.[10] To avoid erroneously attributing variations in bilateral PCIs to the two effects of interest, it is important to have as complete as possible a set of control variables in the vector of "deep" determinants. The $\alpha$ and $\beta$ coefficients control for "deep" determinants of bilateral trade, the former relating to gravity-type equations, and the latter including other controls. The gravity-type controls include log distance ($DIST_{ij}$), the extent of the potential market ($MKT_{ij} = \ln(GDP_i * GDP_j)$), proxied by the product of GDPs (since these cannot be entered individually in the presence of fixed effects), common religion ($CR_{ij}$), common language ($CL_{ij}$) and landlockedness ($LL_{ij}$).

$$\begin{aligned} \ln Z_{ij}^k &= \alpha_0 + \alpha_1 DIST_{ij} + \alpha_2 MKT_{ij} + \alpha_3 CR_{ij} + \alpha_4 CL_{ij} + \alpha_5 LL_{ij} \\ &+ \beta_{1i} DE_i + \beta_{2j} DM_j + \beta_3 \Delta SK_{ij} + \beta_4 \Delta HK_{ij} + \beta_5 \Delta COAL_{ij} + \beta_6 \Delta OIL_{ij} \\ &+ \gamma_1 \Delta LEAD_{ij} + \gamma_2 \Delta KL_{ij} + \varepsilon_{ij} \end{aligned} \tag{3}$$

Other controls include importer ($DM_j$) and exporter ($DE_i$) fixed effects. These dummy variables control for country-specific omitted determinants. As further control variables, we include proxies for differences in natural resource

[9] This index is one of the few available proxies for environmental stringency for a large number of countries that covers the 1980s. It is a market-share weighted sum of the maximum lead content of different gasolines (see Grether and Mathys (2003) and appendix 1 for further details). Hilton and Levinson (1998), Damania et al. (2003), Fredriksson et al (2005) and Cole et al. (2006) also use this proxy for environmental policy.

[10] An advantage of the gravity model over the earlier standard factor endowment-based studies (e.g. Tobey (1990), is that it exploits the large amount of information contained in bilateral trade flows. It was first applied by van Beers and van den Bergh (1997) on a cross section of OECD countries. This initial approach has been extended in a number of directions, including the panel dimension (Harris et al (2001)), developing countries (Cagatay and Mihci (2003) and Grether and de Melo (2004)) the role of product differentiation (Jug and Mirza (2005)) or of regional free trade agreements (Kahn and Yoshino (2004)), while the endogeneity of environmental policy has been examined in Mantovani and Vancauteren (2005).

endowments across countries, oil production ($\Delta OIL_{ij} = \ln(\frac{OIL_i}{OIL_j})$) and coal production ($\Delta COAL_{ij} = \ln(\frac{COAL_i}{COAL_j})$) since it is known that many activities that generate pollution are linked with the weight-reducing activities associated with the processing of primary products. We also include two measures of skills since it has sometimes been claimed that pollution intensive activities are also skill-intensive (see Cole and Elliott (2005)). The two variables are differences in the skill ratio (i.e. (skilled+ base skills)/unskilled labor) ($\Delta SK_{ij} = \ln(\frac{SK_i}{SK_j})$), and differences in the ratio of high skilled labor (skilled/base skills), ($\Delta HK_{ij} = \ln(\frac{HK_i}{HK_j})$). To sum up, one may expect these control variables to be related to the bilateral PCI, although their precise influence is ultimately an empirical matter.

To these variables we add the PH and FE variables mentioned above, namely the difference in the maximum lead content of gasoline ($\Delta LEAD_{ij} = \ln[\frac{LEAD_i}{LEAD_j}]$), and the difference in capital-labor ratios ($\Delta KL_{ij} = \ln[\frac{KL_i}{KL_j}]$).

In equation 3, the 'deep' determinants are given in the first two lines and are followed by the measures of interest in the third line. The regression is run for each one of the three selected pollutants for average values over the 1986-88 period.[11] To account for the possibility that $LEAD$ may be endogenous (as suggested by Ederington and Minier (2003) who found evidence that environmental policy has partly served as a substitute for protection using aggregate data), we instrument $LEAD$ by the UN's measure of Human development (the $HDI$) which is a priori not correlated with the errors, while its significant correlation with $LEAD$ is -0.47.

Recall that the purpose of the estimates is to carry out subsequent simulations that will decompose the regional PCI into its three components identified above. Aside from obvious robustness checks (see below), two objections could be raised to estimates derived from (3). The first relates to the results being entirely driven by the volume of trade rather than the composition of the latter. The second relates to the selection of the sample over which (3) should be estimated.

Regarding the first criticism, one may argue that our results are basically driven by the volume of trade and hence scale effects. We address this potential shortcoming by regressing the *average* ($G^k_{ij}$) instead of the *total* PCI ($Z^k_{ij}$) and hence focusing only on the composition effect. As the trade volume dimension is absent, the traditional gravity-type control variables should in principle all disappear. However, we maintain distance as a regressor to control for the fact that dirty industries are predominantly weight-reducing activities (see e.g. Grether and de Melo (2004)) and might hence be particularly sensitive to transport costs. The alternative specification then becomes:

[11] In the regression, we use only trade flows above a threshold value of \$ 10'000.

$$\ln G_{ij}^{k} = \widetilde{\alpha}_0 + \widetilde{\alpha}_1 DIST_{ij} + \widetilde{\beta}_{1i} DE_i + \widetilde{\beta}_{2j} DM_j \qquad (4)$$
$$+\widetilde{\beta}_3 \Delta SK_{ij} + \widetilde{\beta}_4 \Delta HK_{ij} + \widetilde{\beta}_5 \Delta COAL_{ij} + \widetilde{\beta}_6 \Delta OIL_{ij}$$
$$+\widetilde{\gamma}_1 \Delta LEAD_{ij} + \widetilde{\gamma}_2 \Delta KL_{ij} + \widetilde{\varepsilon}_{ij}$$

As to the sample over which estimation should take place, one might object that since one is interested in the PH effect, all intra-regional bilateral trade (i.e. N-N and S-S) should be deleted. Thus, as a robustness check, we also report estimates of (3) over a sample that excludes intra-regional trade. However as intra-regional trade should also respond to the same determinants as N-S and S-N trade and since we are interested in capturing the PH and FE effects at the worldwide level, we consider that the relevant coefficient estimates for the decomposition exercise are those derived from the whole sample.

Table 2 reports results for the two specifications (3 and 4) and the two samples (world or NS only) for the three pollutants mentioned above ($SO_2$, BOWT, and TPTT). Overall, results are encouraging. Start with estimates of equation (3). First, the signs of the variables of interest are as expected in all specifications, and significant most of the time. The same comment applies to the gravity-related controls. As to the other controls for which we have no a priori expectations, they are only significant in some specifications. Second, the results are quite similar across all 10 pollutants.[12]

**Table 2 here**: Pollution Content of Imports Regressions

As to the comparison between OLS and 2SLS estimates for equation (3), coefficients do not change sign and except for BOWT are very similar in terms of significativity for all variables apart from LEAD, which becomes significant through the instrumentation. In the absence of more suitable instruments and the likelihood of endogeneity, we rely on the 2SLS estimates. As to the robustness of our specification, reassuringly, when we abstract from volume effects, and hence focus on detecting PH and FE effects in the composition of bilateral trade (equation (4)), we still find the same signs for both variables of interest. Finally, estimates are sufficiently close when the sample is restricted to North-South bilateral trade flows indicating that the results of decompositions reported below would not be sensitive to the choice of sample. However in two out of three cases the contribution of the FE effect would be larger if we were to carry out decompositions based on this restricted sample.

Overall, we retain from the estimates in table 2 that the data support the presence of PH and FE effects. The average values of endowments and policies reported in table 1 allow one to deduce the sign of these effects on $PCI_{NS}$ and $PCI_{SN}$. Thus, starting from the "deep" determinants of bilateral trade, the $PCI_{NS}$ will be reduced through the 'FE' effect because the North has a comparative advantage in dirty products. Likewise, because of more stringent

[12] With the exception of total metal pollution where the PH and FE effects are reversed.

environmental standards, the $PCI_{NS}$ will be increased through the 'PH' effect. The opposite patterns will hold for $PCI_{SN}$. However, to go further, we need to take into account the fact that there is horizontal trade which will be reflected in $PCI_{NN}$ and $PCI_{SS}$ values with the worldwide effect being a weighted average of vertical and horizontal trade flows. We now carry out a decomposition of the PCI into its constituents parts.

### 3.2 Decomposing the PCI into the PH and the FE effects

Let $TOT$ stand for the total percentage increase of the PCI of a given region when, starting from deep determinants, and successively introducing the FE and the PH effects, with the corresponding percentage increases of the PCI denoted by $FE$ and $PH$ respectively. Then for each pollutant $k$:

$$1 + TOT = (1 + FE)(1 + PH) \tag{5}$$

The decomposition results are reported in Table 3 for all combinations of import flows and for each pollutant. The table reports (in lines) vertical flows (NS+SN), then horizontal flows (NN+SS), with the total ('world') effect coming last. Along a given column, whathever the effect ($FE$, $PH$ or $TOT$), the aggregate result (i.e. vertical, horizontal or world PCI) is equal to the weighted average of two components (i.e. NS/SN, NN/SS or vertical/horizontal) using as weights the share of the component in the relevant PCI ( i.e.$\Omega$ for the $FE$ and $TOT$ effects, $\Omega\kappa$ for the $PH$ effect).

Consider for example the worldwide decomposition for biological oxygen demand in water reported in the row identified by "$World$" as import flow. Starting from the base pollution content of trade, adding differences in factor endowments reduces the PCI by 4%. Adding differences in environmental regulations increases the PCI by 11%. Taken together, the two effects increase the world PCI by 7%.

Then, if we focus on the PH effect, the worldwide result of 11% is in fact a weighted average between the PH effect on horizontal flows (13%) and the PH effect on vertical flows (1%), with corresponding weights of 88% and 12%. The aggregate PH effect on vertical flows can itself be decomposed into its Northern (173%) and its Southern (-70%) component, with import shares being respectively 29% and 71%.

**Table 3 here**: Decomposition of the PCI into the PH and the FE Effects

Analyzing results in table 3, five patterns stand out. First, as emphasized by those involved in the PH debate, for imports of the North (from the South) whatever the pollutant, the PH effect leads to a strong increase in the PCI while the FE effect has also a strong impact, but in the opposite direction. Second, a reverse pattern of similar magnitude takes place in the PCI of the South (from the North). Third, these countervailing forces naturally tend to compensate each other, so that the FE and PH effects on overall vertical trade are several orders of magnitude smaller than on isolated (either Northern or Southern) PCI flows. As could be expected, the net impact is driven by the Northern pattern, but the mitigating impact of the Southern PCI (at least more than a quarter of vertical PCI) should not be underestimated. Fourth, similar composition effects tend to reduce the estimated impact of the FE and the PH effect on the world PCI because environmental policy and endowment differences are considerably smaller for horizontal trade, which accounts for more than 75% of world PCI. Fifth, for two out of three pollutants, the PH effect dominates the FE effect whatever the type of imports considered, while for the third pollutant (biological oxygen demand), the PH effect is only dominated in the case of Northern imports from the South.

Although these results should be viewed as illustrative, they also give an estimate of the extent of reduction in the worldwide pollution of trade that would occur if there were a complete harmonization of environmental policies. The harmonization effect can be approximately read off the relevant PH columns in table 3 by changing the sign.[13] Taking all 10 pollutants, harmonization would reduce the total PCI by 3%.

As a sensitivity test to the results in table 3, we computed confidence intervals for the predicted values of the different PCI levels. Results are reported in table A4 (available upon request). The sign of the individual effects do not change most of the time, but there are several changes in the total effects. Aggregate worldwide effects remain small, and one can conclude that we obtain the same orders of magnitude.

As composition effects across regions happen to matter, another natural robustness check is to change the GDP per capita threshold above which a country is considered to be a developed economy (US$ 11'000 in the original calculations). Two alternative thresholds have been considered, in order to add or take away five countries to the original group of 19 Northern countries (vs. 29 Southern countries). As can be seen in table A5 (available upon request), the overall patterns are quite insensitive to this change of definition.

# 4 Conclusions

This paper contributes to the debate on trade and the environment by extending the usual case studies (one country or a few products) to a systematic analyis of the content of individual pollutants in global trade at the most disaggregated level for which there is available emission data. While the results share the limitations of other studies due to the absence of more systematic emission data, the paper goes beyond the contributions to the debate that focus on a handful of 'dirty' industries or a case study of a specific pollutant. In our unraveling of the PH effect, we have controlled for the transport cost component of the PCI

[13] The exact variation would be given by $-\frac{(x/100)}{1+(x/100)}$ where x is the percentage change reported in table (3).

as well as other 'deep' determinants of the bilateral pollution content of trade, thereby allowing us to isolate the role of differences in factor endowments and environmental policies.

We do find evidence of traditional PH and FE effects that have often been elusive in the literature. Thus the PCI of the North is lowered because on average its endowments are favorable to activities with high emissions and likewise its PCI is higher because of the probable delocalization of dirty industries to the South associated with stricter environment policies in the North. Symmetrically, we measure the contribution (in the opposite direction) of the PH and FE on the South's PCI. However, because unlike other studies, by carrying out our analysis on global trade which includes the dominant share of North-North trade, we are able to place the PH and PE effects in a proper context. For each one of the 10 pollutants we find that these effects contribute to less than 10% of the overall determinants of emissions. At least for the 1986-88 period, it would appear that differences in factor endowments and environmental policies have only marginally affected the pollution content of world trade although the impact has been stronger on vertical (North-South) trade flows.

In the absence of time-series data, we cannot check if these patterns are stable over time so that more conclusive evidence on the PH debate will have to wait until the availability of comparable data over time on environmental policy, abatement cost or emissions, and on disaggregated trade policy measures at the sector level across a large sample of countries in which developing countries are systematically covered. Much like in an earlier debate around the Leontief paradox regarding the factor content of US trade, better data will be required to get a firmer grasp of the quantitative importance of the effects involved.

# References

[1] Antweiler, B. Copeland and S. Taylor (2001),"Is Free Trade Good for the Environment? " *American Economic Review*, Vol. 91(4), pp.877-908.

[2] Cagatay S, and H. Mihci (2006), "Degree of Environmental Stringency and the Impact on Trade Patterns", *Journal of Economic Studies,* Vol. 33(1), pp. 30-51.

[3] CIA's World Factbook: http://www.cia.gov/cia/publications/ factbook/docs/profileguide.html.

[4] Cole, M.A (2004), "US Environmental Load Displacement: Examining Consumption, Regulations and the Role of NAFTA", *Ecological Economics*, Vol. 48(4), pp. 439-50.

[5] Cole, M.A., R.J.R. Elliott and P. Fredriksson (2006), "Endogenous Pollution Havens: Does FDI Influence Environmental Regulations?" *Scandinavian Journal of Economics*, Vol. 108 (1), pp. 157-178.

[6] Cole, M.A. and R.J.R. Elliott (2005), "FDI and the Capital Intensity of "Dirty" Sectors: A Missing Piece of the Pollution Haven Puzzle", *Review of Development Economics*, Vol. 9(4), pp. 530-548.

[7] Cole, M.A, R.J.R. Elliott and K. Shimamoto (2004), "Why the Grass is not Always Greener: The Competing Effects of Environmental Regulations and Factor Intensities on US Specialization", mimeo, University of Nottingham.

[8] Cole, M.A. and R.J.R. Elliott (2003), "Do Environmental Regulations Influence Trade Patterns? Testing Old and New Trade Theories", *The World Economy*, Vol. 26 (8), pp. 1163-86.

[9] Cole, M.A. and R.J.R. Elliott (2003), "Determining the Trade-Environment Composition Effect: The Role of Capital, Labor and Environmental Regulations", *Journal of Environmental Economics and Management*, Vol. 46 (3), pp. 363-383.

[10] Copeland, B.R. and M.S. Taylor (2004), "Trade, Growth and the Environment", *Journal of Economic Literature*, Vol. 42, pp. 7-71.

[11] Copeland, B.R. and M.S. Taylor (2003), *Trade and the Environment: Theory and Evidence*, Princeton University Press.

[12] Damania, R., P.G. Fredriksson and J.A. List (2003)," Trade Liberalization, Corruption and Environmental Policy Formation: Theory and Evidence", *Journal of Environmental Economics and Management*, Vol. 46(3), pp. 490-512.

[13] Ederington, J. and J. Minier, (2003), "Is Environmental Policy a Secondary Trade Barrier? An Empirical Analysis", *Canadian Journal of Economics*, Vol. 36(1), pp. 137-54.

[14] Ederington, J., A. Levinson and J. Minier, (2004), "Trade Liberalization and Pollution Havens", *Advances in Economic Analysis & Policy*, Vol. 4 (2), Article 6.

[15] Ederington, J., A. Levinson and J. Minier, (2005), "Footloose and Pollution-Free ", *The Review of Economics and Statistics*, Vol. 87(1), 92-99.

[16] Eskeland, G. and A. Harrison, (2002), "Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis", *Journal of Development Economics",* Vol. 63(1), pp. 1-23

[17] Frankel, J. and A. Rose, (2005), "Is Trade Good for the Environement? Sorting out the Causality", *The Review of Economics and Statistics,* Vol. 87(1), pp.85-91.

[18] Fredriksson, P.G., E. Neumayer, R. Damania and S. Gates (2005), "Environmentalism, Democracy and Pollution Control", *Journal of Environmental Economics and Management,* Vol.45, pp.343-365.

[19] Grether, J.-M. and N.A. Mathys (2002), Lead content of gasoline 1983-1995, University of Neuchâtel, Switzerland.

[20] Grether, J.-M. and J. de Melo, (2004), "Globalization and dirty industries: Do pollution havens matter?" in R.E. Baldwin and A. Winters eds., *Challenges to Globalization: Analyzing the Economics*, University of Chicago Press, pp. 167-208.

[21] Grether, J.-M. , N. Mathys and J. de Melo, (2006), "Decomposing the Worldwide Pollution Content of Trade, 1986-1996 ", mimeo, University of Neuchâtel.

[22] Harris, M., L. Konya and M. Matyas, (2001), "Modelling the Impact of Environmental Regulations on Bilateral Trade Flows: OECD 1990-96", mimeo, University of Melbourne.

[23] Hettige, H.P., M. Mani and Wheeler, D. (2000), "Industrial Pollution in Economic Development: The Environmental Kuznets Curve Revisited", *Journal of Development Economics",* Vol. 62(2), pp. 445-76

[24] Hettige, H.P., Martin, P., Singh, M. and Wheeler, D. (1995), "The Industrial Pollution Projection System", WPS# 1431, The World Bank, Washington, D.C.

[25] Hilton, F. G. H., and A. Levinson (1998). "Factoring the Environmental Kuznets Curve: Evidence from Automotive Lead Emissions," *Journal of Environmental Economics and Management*, Elsevier, Vol. 35(2), pp. 126-141.

[26] ISHAM, I., L. PRITCHETT, M. WOOLCOCK AND G. BUSBY, (2005), "The Varieties of Resource Experience: Natural Resource Export Structures and the Political Economy of Economic Growth", *World Bank Economic Review,* Vol. 19(2), pp. 141-74.

[27] JUG, J. AND D. MIRZA, (2005), "Environmental Regulation in Gravity Equations: Evidence from Europe", *The World Economy*, Vol. 28(11), pp. 1591-615.

[28] KAHN, M. AND Y. YOSHINO (2004), "Testing the Pollution Havens Inside and Outside of Regional Trading Blocs", *Advances in Economic Analysis & Policy*, Vol. 4 (2), Article 4.

[29] LEVINSON, A. AND S. TAYLOR, (2005),"Unmasking the Pollution Haven Effect", mimeo, Georgetown University and revised NBER # 10629.

[30] MANI, M. and WHEELER, D., (1997), "In Search of Pollution Havens? Dirty Industry in the World Economy, 1960-95", in P. Fredriksson (ed), Trade, Global Policy, and the Environment, WBDP # 402, World Bank, pp. 115-128.

[31] MANTOVANI, A. AND M. VANCAUTEREN (2004), "Environmental Policy and Trade in the Single Market", mimeo, Louvain.

[32] MURADIAN, R., M. OCONNOR AND J. MARTINEZ-ALIER, (2002), "Embodied pollution in trade: estimating the 'environmental load displacement' of industrialised countries", *Ecological Economics* , Vol. 41, pp. 51-67.

[33] OLARREAGA, M. AND A. NICITA (2001), "Trade and Production, 1976-99", World Bank Database.

[34] TOBEY, J. (1990), "The Effects of Domestic Environmental Policies on Patterns of World Trade : An Empirical Test", *Kyklos*, Vol. 43 (2), pp. 191-209.

[35] VAN BEERS, C. AND J. VAN DEN BERGH, (1997), "An Empirical Multi-Country Analysis of the Impact of Environmental Regulation on Foreign Trade Flows", *Kyklos*, Vol. 50 (1), pp. 29-46.

**Tables and Appendices to**

**Unraveling the World-Wide Pollution Haven Effect**
**By J.-M. Grether, N. A. Mathys and J. de Melo**

**August, 2006**

**Table 1: Summary Statistics**

| Variable (units) | Statistics | North** (19 countries) | South** (29 countries) |
|---|---|---|---|
| **Lead Content** | | | |
| (Grams / Gallon) | Mean | 0.24 | 0.58 |
| | Min | 0.0002 | 0.16 |
| | Max | 0.74 | 0.96 |
| | C.V. | 0.76 | 0.43 |
| **Capital/Labor** | | | |
| (1987 Thousand US Dollars) | Mean | 88.94 | 9.67 |
| | Min | 27.03 | 0.97 |
| | Max | 159.02 | 35.76 |
| | C.V. | 0.38 | 0.89 |
| **Imports*** | | | |
| (Million Current US Dollars) | Mean | 930 | 99 |
| | Min | 101 | 5 |
| | Max | 5'546 | 510 |
| | C.V. | 1.34 | 1.30 |
| **PCI-BOWT*** | | | |
| (Million Pounds) | Mean | 1.19 | 0.17 |
| | Min | 0.11 | 0.01 |
| | Max | 5.97 | 0.59 |
| | C.V. | 1.29 | 1.00 |
| **PCI-$SO_2$*** | | | |
| (Million Pounds) | Mean | 7.24 | 1.27 |
| | Min | 0.71 | 0.07 |
| | Max | 38.10 | 7.70 |
| | C.V. | 1.31 | 1.32 |
| **PCI-TPTT*** | | | |
| (Million Pounds) | Mean | 5.39 | 0.86 |
| | Min | 0.56 | 0.05 |
| | Max | 24.70 | 3.57 |
| | C.V. | 1.18 | 1.11 |

Notes:
C.V: Coefficient of variation.
* Bilateral data has been averaged by importer.
** For income group definition see table A1 in the appendix.

**Table 2: Pollution Content of Imports Regressions, 1986/1988**

| | Biochemical Oxygen Demand Water (BOWT) | | | | $SO_2$ in the Air ($SO_2$) | | | | Total Toxic Pollution Intensity (TPTT) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total PCI | | Av. PCI | NS PCI | Total PCI | | Av. PCI | NS PCI | Total PCI | | Av. PCI | NS PCI |
| | OLS | 2SLS | 2SLS | 2SLS | OLS | 2SLS | 2SLS | 2SLS | OLS | 2SLS | 2SLS | 2SLS |
| **ΔLead** | -0.16*** | -0.32*** | -0.39*** | -0.39*** | -0.02 | -0.21*** | -0.19*** | -0.20*** | -0.01 | -0.21*** | -0.20*** | -0.21*** |
| | [5.31] | [5.22] | [10.28] | [5.37] | [0.60] | [3.86] | [6.53] | [3.05] | [0.52] | [4.26] | [7.71] | [3.36] |
| **Δ Capital/Labor** | -0.11 | -0.29*** | -0.42*** | -0.2 | -0.18** | -0.16** | -0.36*** | -0.44*** | -0.19** | -0.12* | -0.41*** | -0.32*** |
| | [1.22] | [3.29] | [6.22] | [1.54] | [2.44] | [2.05] | [7.01] | [3.76] | [2.18] | [1.77] | [9.04] | [2.95] |
| **Δ Skill Ratio[a)]** | 0.09 | 0.33** | -0.23* | -0.05 | 0.50*** | 0.47*** | -0.14 | 0.18 | 0.38*** | 0.30** | -0.50*** | -0.04 |
| | [0.81] | [1.97] | [1.93] | [0.33] | [5.24] | [3.14] | [1.48] | [1.29] | [4.22] | [2.20] | [6.18] | [0.33] |
| **Δ High Skill Ratio[b)]** | -0.18 | -1.89*** | 0.17 | -1.20*** | -0.62*** | -2.08*** | 0.21 | -0.97*** | -0.43* | -1.78*** | 0.92*** | -0.55** |
| | [0.75] | [7.64] | [0.91] | [4.59] | [3.17] | [9.44] | [1.46] | [4.08] | [1.91] | [9.01] | [7.30] | [2.45] |
| **ΔCoal** | -0.02 | 0.01 | -0.10*** | 0.14*** | 0.03** | 0.04** | -0.09*** | 0.18*** | 0 | 0.01 | -0.16*** | 0.14*** |
| | [0.79] | [0.43] | [5.88] | [3.80] | [2.03] | [2.19] | [6.52] | [5.38] | [0.02] | [0.36] | [13.50] | [4.51] |
| **ΔOil** | 0.03 | 0 | 0.01 | 0.28*** | 0.05*** | 0.02 | 0.02 | 0.27*** | 0.04* | 0 | -0.01 | 0.22*** |
| | [1.04] | [0.07] | [0.74] | [5.82] | [2.93] | [0.66] | [1.21] | [6.09] | [1.98 | [0.18] | [0.51] | [5.12] |
| **Distance** | -1.34*** | -1.34*** | -0.24*** | -1.55*** | -1.32*** | -1.32*** | -0.20*** | -1.51*** | -1.25*** | -1.25*** | -0.11*** | -1.39*** |
| | [15.35] | [21.23] | [5.91] | [13.12] | [15.96] | [23.58] | [6.39] | [14.05] | [15.87] | [24.95] | [3.92] | [13.59] |
| **$GDP_i$*$GDP_j$** | 0.94*** | 0.55*** | | 0.61*** | 0.96*** | 0.59*** | | 0.63*** | 0.93*** | 0.57*** | | 0.61*** |
| | [22.00] | [43.30] | | [28.91] | [24.74] | [51.77] | | [32.56] | [22.33] | [56.43] | | [33.73] |
| **Common Language** | 1.14*** | 1.14*** | | 0.50*** | 1.00*** | 1.00*** | | 0.70*** | 0.92*** | 0.92*** | | 0.49*** |
| | [7.52] | [8.24] | | [2.93] | [6.74] | [8.15] | | [4.53] | [6.79] | [8.34] | | [3.37] |
| **Common Religion** | 0.72*** | 0.72*** | | 0.34 | 0.74*** | 0.74*** | | 0.37* | 0.67*** | 0.67*** | | 0.35* |
| | [5.18] | [4.52] | | [1.63] | [5.34] | [5.25] | | [1.94] | [6.42] | [5.29] | | [1.92] |
| **Landlocked** | -0.67** | -2.08*** | | -0.44 | -0.46* | -1.57*** | | 0.11 | -0.54** | -1.54*** | | -0.43 |
| | [2.49] | [7.67] | | [1.33] | [1.99] | [6.52] | | [0.35] | [2.11] | [7.13] | | [1.50] |
| **Observations** | 2107 | 2107 | 2107 | 1109 | 2107 | 2107 | 2107 | 1109 | 2107 | 2107 | 2107 | 1109 |
| **R-squared** | 0.73 | 0.73 | 0.34 | 0.78 | 0.74 | 0.74 | 0.47 | 0.8 | 0.78 | 0.78 | 0.49 | 0.81 |

Notes:

Dependent variable (in log): Total PCI: Total bilateral PCI, Av. PCI: Average bilateral PCI, NS PCI: Total bilateral PCI between North and South.

Absolute value of t statistics in brackets, in 2SLS regressions lead is instrumented with the human development index, first stage F statistics are 48.50 for the average PCI regressions and 56.43 for the others, fixed effects are not reported.

* significant at 10%; ** significant at 5%; *** significant at 1%, [a)] (skilled+base skills) / unskilled, [b)] skilled / base skills

**Table 3: Decomposition of the PCI into the FE and the PH-Effect (%)**

| Import Flows [a] | Number of observations | Biochemical Oxygen Demand Water (BOWT) | | | $SO_2$ in the Air ($SO_2$) | | | Total Toxic Pollution Intensity (TPTT) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | FE-Effect | PH-Effect | TOT-Effect | FE-Effect | PH-Effect | TOT-Effect | FE-Effect | PH-Effect | TOT-Effect |
| **NS** | **544** | -86 | 173 | -14 | -44 | 114 | 20 | -38 | 106 | 27 |
| **SN** | **565** | 127 | -70 | -33 | 61 | -65 | -44 | 42 | -64 | -49 |
| **NS+SN** | **1109** | -19 | 1 | -19 | -13 | 15 | 1 | -8 | 8 | -1 |
| **NN** | **342** | -1 | 13 | 12 | -1 | 9 | 9 | 0 | -3 | -3 |
| **SS** | **656** | -22 | -16 | -34 | -1 | -6 | -7 | -5 | -9 | -13 |
| **NN+SS** | **998** | -2 | 13 | 11 | -1 | 9 | 8 | 0 | -3 | -4 |
| **World** | **2107** | -4 | 11 | 7 | -3 | 10 | 6 | -2 | -1 | -3 |
| | | **$\Omega$** | **$\Omega\ \kappa$** | **$\Omega\ \kappa\ell$** | **$\Omega$** | **$\Omega\ \kappa$** | **$\Omega\ \kappa\ell$** | **$\Omega$** | **$\Omega\ \kappa$** | **$\Omega\ \kappa\ell$** |
| **Share of NS in NS+SN** | | 75 | 29 | 79 | 70 | 45 | 83 | 63 | 42 | 81 |
| **Share of NN in NN+SS** | | 97 | 98 | 98 | 95 | 96 | 96 | 95 | 95 | 95 |
| **Share of NS+SN in World** | | 14 | 12 | 11 | 22 | 20 | 21 | 24 | 22 | 24 |

Notes:

[a] NS: North imports from the South, SN: South imports from the North, NN: North imports from the North, SS: South imports from the South.

Along lines: TOT = (1+FE)*(1+PH) -1, Along columns: $AGG_v = \theta * CMP_1 + (1-\theta) * CMP_2$ where $AGG_v$ is the aggregate effect (v = NS+SN, NN+SS, World) $CMP_1$ and $CMP_2$ are the two corresponding components and θ is the share of $CMP_1$ in the relevant PCI (**$\Omega$** for the FE and the TOT effects, **$\Omega\ \kappa$** for the PH effect , **$\Omega\ \kappa\ell$** is only reported for the sake of completeness).

## Appendices
## (not submitted for publication)

### A1: Data Description

Bilateral trade flows are taken from the "Trade and Production Database" by Olarreaga and Nicita (2001). Imports (imports are known to be more reliable than exports) for 48 developing and developed countries are available at the 4-digit ISIC level (see appendix A1 for a country-list).

In order to transform these real bilateral trade flows into the pollution content of imports we need some measure of pollution intensity by sector. For this purpose we use the World Bank's "Industrial Pollution Pojection System" (IPPS), see Hettige et al. (1995) for a detailed description. These IPPS coefficients allow us to estimate the amout of pollution (in pounds or kilograms) emitted per employee by 4-digit ISIC. In total 10 different pollutants (see table A3 in Appendix 2 for a detailed list of these pollutants) are proposed. Concerning the exact measure, we use the lower bound estimation of pollution per employee. Note that these IPP coefficients are strictly speaking only available for 1987 for the US industries. Hettige, Mani and Wheeler (2000) show that pollution/labor ratios seem to be roughly constant across countries. Hence using employment/output ratios by 3-digit industry (4-digit data are not available) and country from the "Trade and Production Database " allows us to compute a pollution per dollar of import coefficient specific to each country.

The distance and the common language variable are taken from the cepii database, the common religion variable has been constructed on the basis of the CIA's World factbook and the GDP values are extracted from the World Development Indicators 2004 (WB). Capital and labor endowment data are extracted from Sandeep Mahajan (PRMEP), World Bank 2001. The skill ratios and coal and oil production have been used from the paper by Gourdon, Maystre and de Melo (2006). The human development index for 1987 has been extracted from the UN website.

The database for the maximum lead content in gasoline has been elaborated by Grether and Mathys (2002) on the basis of Octel's Worldwide Gasoline Survey. More precisely the average has been worked out by using different types of gasoline and weighting them by their market share. Therefore, the proxy constructed takes into account the importance of the different types of gasoline in the overall market. If one admits that it is generally more costly to produce gasoline with low lead contents, the selected variable represents not only the maximum lead content observed, but also, and this is the important feature, in some sense the enforced legal limit of lead content in gasoline. Since it is impossible for the moment to obtain an index of environmental stringency for the 80s for a large set of countries, the average maximum lead content represents at least one of the most important environmental indicator. Note also that Damania et al (2003) showed that this indicator is closely correlated with other proxies for environmental stringency.

## A2: Appendix Tables

**Table A1: Countries in the sample**

| | |
|---|---|
| Argentina | Jordan |
| Australia* | Japan* |
| Austria* | Kenya |
| Bolivia | Korea, Rep. |
| Canada* | Sri Lanka |
| Chile | Mexico |
| China | Malawi |
| Cameroon | Malaysia |
| Colombia | Netherlands* |
| Costa Rica | Norway* |
| Denmark* | New Zealand* |
| Ecuador | Pakistan |
| Egypt, Arab Rep. | Panama |
| Spain* | Peru |
| Finland* | Philippines |
| France* | Portugal* |
| United Kingdom* | Singapore* |
| Greece* | Sweden* |
| Guatemala | Thailand |
| Honduras | Trinidad and Tobago |
| Indonesia | Turkey |
| India | Uruguay |
| Ireland* | United States* |
| Italy* | Venezuela, RB |

Note: (*) stands for developed economies, e.i. economies where the average GDP per capita over the sample period in 1995 PPP dollars is higher than $11'000.

**Table A2: Dirty and Clean Sectors**

| Dirty | | Clean | |
|---|---|---|---|
| ISIC 3-digit | Description | ISIC 3-digit | Description |
| 341 | Paper and products | 321 | Textiles |
| 351 | Industrial chemicals | 382* | Machinery except electrical |
| 369 | Other non-metallic mineral products | 383* | Machinery electrical |
| 371 | Iron and steel | 384 | Transport equipment |
| 372 | Non-ferrous metals | 385 | Professional and scientific equipment |

Note: * These sectors have been classified as overall clean. When only looking at pollution intensity in heavy metals however they are on ranks 8 and 9 respectively.
Source: Copeland and Taylor (2003).

**Table A3: Pollutants**

| IPPS-Pollutants - per employee, lower bound | | Pollution share of dirty sectors (in %)* |
|---|---|---|
| TPTT | Toxic pollution intensity - TOTAL | 73 |
| MPTT | Toxic metal pollution intensity - TOTAL | 85 |
| S2AI | SO2 - AIR | 65 |
| N2AI | NO2 - AIR | 61 |
| COAI | CO - AIR | 59 |
| VOAI | Volatile organic compounds - AIR | 59 |
| FPAI | Fine particulates - AIR | 64 |
| TSAI | Total suspended particulates - AIR | 48 |
| BOWT | Biochemical oxygen demand - WATER | 79 |
| TSWT | Total suspended solids - WATER | 91 |

Note: * Dirty sectors account for 18% of total imports.

**Table A4: Confidence Intervals for the decomposition estimates (%)**

| | | Biochemical Oxygen Demand Water (BOWT) | | | $SO_2$ in the Air ($SO_2$) | | | Total Toxic Pollution Intensity (TPTT) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Import Flows [a)]** | **Number of Observations** | **FE-Effect** | **PH-Effect** | **TOT Effect** | **FE-Effect** | **PH-Effect** | **TOT Effect** | **FE-Effect** | **PH-Effect** | **TOT Effect** |
| **NS** | **544** | -75 ; -60 | 167 ; 180 | -34 ; 12 | -53 ; -34 | 107 ; 122 | -3 ; 47 | -48 ; -27 | 101 ; 111 | 4 ; 55 |
| **SN** | **565** | 118 ; 138 | -77 ; -63 | -50 ; -11 | 56 ; 66 | -73 ; -55 | -58 ; -26 | 38 ; 47 | -72 ; -56 | -61 ; -35 |
| **NS+SN** | **1109** | -26 ; -11 | -17 ; 20 | -38 ; 6 | -18 ; -5 | -3 ; 33 | -20 ; 26 | -15 ; -1 | -8 ; 23 | -21 ; 23 |
| **NN** | **342** | -1 ; -1 | 9 ; 17 | 8 ; 16 | -1 ; 0 | 5 ; 13 | 4 ; 13 | 0 ; 0 | -7 ; 0 | -7 ; 1 |
| **SS** | **656** | -26 ; -18 | -16 ; -15 | -38 ; -31 | -4 ; 1 | -6 ; -5 | -10 ; -4 | -7 ; -3 | -9 ; -8 | -16 ; -11 |
| **NN+SS** | **998** | -2 ; -1 | 9 ; 16 | 7 ; 15 | -1 ; 0 | 5 ; 12 | 4 ; 12 | 0 ; 0 | -7 ; 0 | -7 ; 0 |
| **World** | **2107** | -6 ; -2 | 5 ; 17 | -1 ; 14 | -5 ; -1 | 3 ; 16 | -2 ; 15 | -4 ; 0 | -7 ; 5 | -11 ; 5 |

Notes:
95% Confidence intervals on the predicted values are reported.
[a)] See notes table 3.

**Table A5: Decomposition of the PCI into the FE and the PH-Effect (in %) with Changing Income Group Definition**

| Import Flows [a] | Income Group Definition [b] | Number of Observations | Biochemical Oxygen Demand Water (BOWT) | | | $SO_2$ in the Air ($SO_2$) | | | Total Toxic Pollution Intensity (TPTT) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | FE-Effect | PH-Effect | TOT Effect | FE-Effect | PH-Effect | TOT Effect | FE-Effect | PH-Effect | TOT Effect |
| **NS** | **Initial** | **544** | **-86** | **173** | **-14** | **-44** | **114** | **20** | **-38** | **106** | **27** |
| | Higher | 473 | -54 | 111 | -3 | -40 | 112 | 27 | -33 | 97 | 31 |
| | Lower | 549 | -69 | 166 | -20 | -46 | 16 | 11 | -40 | 99 | 19 |
| **SN** | **Initial** | **565** | **127** | **-70** | **-33** | **61** | **-65** | **-44** | **42** | **-64** | **-49** |
| | Higher | 489 | 78 | -60 | -28 | 46 | -58 | -38 | 32 | -56 | -42 |
| | Lower | 575 | 164 | -63 | -3 | 76 | -52 | -16 | 52 | -53 | -29 |
| **NS+SN** | **Initial** | **1109** | **-19** | **1** | **-19** | **-13** | **15** | **1** | **-8** | **8** | **-1** |
| | Higher | 962 | -8 | -3 | -12 | -8 | 12 | 3 | -5 | 4 | -1 |
| | Lower | 1124 | -31 | 20 | -17 | -19 | 30 | 5 | -15 | 25 | 6 |
| **NN** | **Initial** | **342** | **-1** | **13** | **12** | **-1** | **9** | **9** | **0** | **-3** | **-3** |
| | Higher | 182 | -1 | 16 | 14 | -1 | 11 | 10 | 0 | -3 | -3 |
| | Lower | 550 | 0 | 11 | 11 | 1 | 7 | 8 | 1 | -6 | -4 |
| **SS** | **Initial** | **656** | **-22** | **-16** | **-34** | **-1** | **-6** | **-7** | **-5** | **-9** | **-13** |
| | Higher | 963 | -33 | -12 | -41 | -12 | -3 | -15 | -11 | -7 | -17 |
| | Lower | 433 | -29 | -21 | -45 | -10 | -11 | -19 | -11 | -14 | -23 |
| **NN+SS** | **Initial** | **998** | **-2** | **13** | **11** | **-1** | **9** | **8** | **0** | **-3** | **-4** |
| | Higher | 1145 | -3 | 15 | 11 | -2 | 9 | 8 | -1 | -3 | -4 |
| | Lower | 983 | 0 | 11 | 10 | -0 | 6 | 7 | 1 | -6 | -5 |

Notes:

[a] See notes table3.

[b] Higher: Treshold at US $ 15'000; Greece, Ireland, Portugal, Singapore and Spain become Southern countries.

[c] Lower: Treshold at US $ 6'500; Argentina, Korea, Mexico, Trinidad Tobago and Uruguay become Northern countries.

**Table A6: Variable Description**

| Variable | Description | Source |
| --- | --- | --- |
| h | Pollution per employee | IPPS, World Bank |
| L/X | Inverse labor productivity | Trade and Production Database, 1976-2000 |
| M | Bilateral import flows | Trade and Production Database, 1976-2000 |
| DIST | Geodesic Distance between the most important cities | http://www.cepii.fr |
| MKT | Product of GDPs | World Bank Development Indicator 2004 |
| CR | Common Religion | Correlation Coefficient, based on CIA's World Factsbook |
| CL | Dummy for common language | http://www.cepii.fr |
| LL | Dummy for landlockedness | http://www.cepii.fr |
| SK | Proportion of population over 15 years with completed primary education with respect to population with less than 4 years of schooling in 1987. | Barro and Lee (2000) |
| HK | Proportion of population over 15 years with completed high education with respect to population with less than 4 years of schooling in 1987. | Barro and Lee (2000) |
| COAL | Production of coal | World Energy Council (2004) |
| OIL | Production of oil | World Energy Council (2004) |
| LEAD | Average maximum lead content in gasoline | Octels world wide gasoline survey, prepaired base available on http://www2.unine.ch/Jahia/site/irene/op/edit/pid/12149?matrix=101 |
| K/L | Capital to labor ratio | Sandeep Mahajan (PRMEP), World Bank 2001 |
| HDI | Human development indicator for 1987 | United Nations Database |